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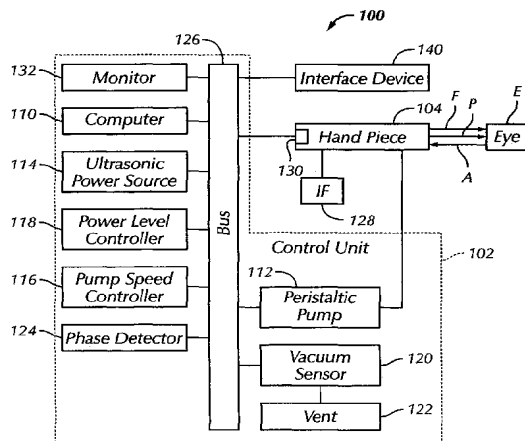
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(54) Title: PHACOEMULSIFICATION SYSTEM UTILIZING GRAPHICAL USER INTERFACES FOR ADJUSTING PULSE PARAMETERS



(57) Abstract: A phacoemulsification system (100) with enhanced user utility and tactile operability includes a control unit (102) and a handpiece with a needle (106) and a vibrating unit (108) that is configured to ultrasonically vibrate the needle (106). The handpiece (104) includes a needle (106) and a vibrating unit (108) for ultrasonically vibrating the needle (106) according to a variable parameter, such as frequency, shape, size, duty cycle, and so on. The control unit (102) is configured to adjust the value of the parameter. A monitor (132) is operably connected to the control unit (102) for displaying a graphical user interface (GUI). The GUI includes an adjustable control element (136), such as a slider bar, radio buttons, or handles, and an indication element (138) that indicates the value of the parameter, either numerically or graphically. An interface device, such as a touchscreen, a mouse, or a keyboard, is operably connected to the control unit (102) for enabling a user to adjust the control element (136). The control unit (102) is configured to change the value of the parameter at least in response to adjustments of the control element (136) by the user.



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## **PHACOEMULSIFICATION SYSTEM UTILIZING GRAPHICAL USER INTERFACES FOR ADJUSTING PULSE PARAMETERS**

### **BACKGROUND OF THE INVENTION**

**[0001]** The invention relates to methods and devices for removing a lens from an eye and, more particularly, phacoemulsification systems.

**[0002]** A number of medically recognized techniques have been utilized for removing a lens from an eye. One such technique is phacoemulsification, which includes making a corneal incision in the eye and then inserting a needle of a handpiece into the eye, with the needle being ultrasonically driven or vibrated in order to emulsify the eye lens. Simultaneously with this emulsification, a fluid is utilized for irrigating the eye, and a vacuum is provided for aspirating the emulsified lens and inserted fluids.

**[0003]** Pulses or signals from a control unit controls the vibration of the needle. The pulses are controlled by one or more parameters, such as frequency, size, shape, and so on. It is inconvenient during a phacoemulsification procedure to change the parameters of the pulses being delivered to the needle in real time without the surgeon being distracted during the change.

**[0004]** In view of the foregoing, there remains a need in the art for a phacoemulsification system that has enhanced user utility and tactile operability so that parameters of the pulses can be changed in real time during a procedure.

### **SUMMARY OF THE INVENTION**

**[0005]** According to one aspect of the invention, a phacoemulsification system with enhanced user utility and tactile operability includes a control unit and a handpiece with a needle and a vibrating unit that is configured to ultrasonically vibrate the needle. The handpiece includes a needle and a vibrating unit for ultrasonically vibrating the needle according to at least one variable parameter, such as frequency, shape, size, duty cycle, amplitude, and so on. The control unit is configured to adjust the value of the parameter that is varied. In a number of embodiments, multiple parameters may be adjusted.

**[0006]** The system also includes a monitor operably connected to the control unit for displaying a graphical user interface (GUI). The GUI includes an adjustable control element, such as a slider bar, radio buttons, or handles, and an indication element that indicates the

value of the parameter, either numerically or graphically. An interface device, such as a touchscreen, a mouse, or a keyboard, is operably connected to the control unit for enabling a user to adjust the control element. The control unit is configured to change the value of the parameter at least in response to adjustments of the control element by the user.

**[0007]** One of the advantages of the invention is that during a phacoemulsification procedure, a surgeon or surgical assistant can view the GUI on the monitor to easily see parameters of the pulse currently being provided to the handpiece. In addition, the surgeon or surgical assistant can easily and tactilely adjust the value of one or more parameters on the same GUI. This greatly increases the utility of the system during a highly refined and sensitive procedure. As mentioned above, in many cases, the values of multiple parameters can be adjusted.

**[0008]** Other features and advantages of the present invention will become apparent to those skilled in the art from a consideration of the following detailed description taken in conjunction with the accompanying drawings.

#### **BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS**

- [0009]** FIG. 1 is a block diagram of a phacoemulsification system;
- [0010]** FIG. 2 schematically illustrates a handpiece of the system in relation to an eye;
- [0011]** FIG. 3 illustrates a commercial embodiment of the invention;
- [0012]** FIG. 4 is a block diagram of a computer and a monitor of the system;
- [0013]** FIG. 5 illustrates a graphical user interface (GUI) according to a number of embodiments;
- [0014]** FIG. 6 illustrates a touchscreen interface device;
- [0015]** FIG. 7 illustrates a mouse interface device;
- [0016]** FIG. 8. illustrates a keyboard interface device;
- [0017]** FIG. 9 illustrates a GUI according to other embodiments;
- [0018]** FIG. 10 illustrates a GUI according to still other embodiments;
- [0019]** FIG. 11 illustrates a GUI according to further embodiments;
- [0020]** FIG. 12 illustrates a footswitch interface device; and

[0021] FIG. 13 illustrates a remote-control interface device.

### DETAILED DESCRIPTION OF THE INVENTION

[0022] Referring to the drawings in more detail, a phacoemulsification system **100** with enhanced user utility and tactile operability is illustrated in FIG. 1. In a number of embodiments, the system **100** may include a control unit **102** and a handpiece **104** operably coupled together. As shown in FIG. 2, the handpiece **104** may include a needle **106** for insertion into an eye E and a vibrating unit **108** that is configured to ultrasonically vibrating needle **106**. The vibrating unit **108**, which may include, e.g., a piezoelectric crystal, vibrates the needle **106** according to one or more parameters, such as frequency, pulse width, shape, size, duty cycle, amplitude, and so on, which is discussed in more detail below. The system **100** is described in general immediately hereunder, with a detailed description of the enhanced user utility and operability of the system following.

[0023] With particular reference to FIG. 1, the functional block diagram of the phacoemulsification system **100** includes a microprocessor computer **110** which is operably connected to and controls the various other elements of the system. In a number of embodiments, the system **100** may include a variable speed pump **112** for providing a vacuum source and a pulsed ultrasonic power source **114** for providing control outputs to a pump speed controller **116** and an ultrasonic power level controller **118**. A vacuum sensor **120** provides an input to the computer **110** representing the vacuum level on the output side of the pump **112**. Venting may be provided by a vent **122**. The system **100** may also include a phase detector **124** for providing an input to the computer **100** that represents a phase shift between a sine wave representation of the voltage applied to the handpiece **104** and the resultant current into the handpiece **104**. The functional representation of the system **100** also includes a system bus **126** for enable the various elements to be operably coupled with each other.

[0024] In operation, the control unit **102** supplies ultrasonic power on to the phacoemulsification handpiece **104**. An irrigation fluid source **128** provides irrigation fluid to the handpiece **104**. The irrigation fluid and an ultrasonic pulse are applied by the handpiece **104** to a patient's eye E, which are indicated by arrows F and P. Aspiration of the eye E is achieved by means of the pump **112**, which is indicated by arrow A. The handpiece **104** may include a switch **130** for enabling a surgeon to select an amplitude of electrical

pulses to the handpiece **104** via the computer **110**, the power level controller **118**, and the ultrasonic power source **114**. The operation of the system **100** in general may be in accordance with the disclosure of U.S. Patent No. 6,629,948, which is incorporated herein in its entirety by reference.

**[0025]** Turning to the enhanced user utility and operability of the system **100** in more detail, the control unit **102** may include a video display or monitor **132** as shown in FIGS. **3** and **4**. The monitor **132** is operably connected to the computer **110** and is configured to display a graphical user interface (GUI) **134**. An example of a GUI **134** is shown in FIG. **4**. The GUI **134** may include one or more adjustable control elements **136** and one or more indication elements **138**. The indication elements **138** either graphically or numerically indicate the value of the operating parameters of the handpiece **104** or the irrigation fluid. For example, as shown in FIG. **5**, indication element **138a** indicates a duty cycle of the pulse, and indication element **138b** indicates the pulse rate of the pulse.

**[0026]** As shown in FIG. **4**, the system **100** may also include an interface device **140** operably connected to the control unit **102** (as shown in FIG. **1**) or the computer **110**. The interface device **140** is configured to enable a user to adjust the control element **136** and, therefore, to change the value of the parameter or parameters of the handpiece **104**. The control unit **102** is configured to change the value of the parameter at least in response to adjustments of the control element **136** by the user. For example, the interface device **140** may include a touchscreen **142** as shown in FIG. **6** integrated with the monitor **132** for tactile or manual adjustment of the control elements **136**, a mouse **144** as shown in FIG. **7** for cursor adjustment of the control elements **136**, or a keypad or keyboard **146** as shown in FIG. **8** for keystroke adjustment of the control elements **136**. The computer **110** may include an interface controller **148** and an interface driver **150** for controlling the interface device **140**. In mouse **144** embodiments, the GUI **134** may display a pointer **151** operatively associated with the mouse **144**.

**[0027]** In a number of embodiments, the computer **110** may be configured to change the values of the parameters in real time in response to any change made with the control elements **136**, with the indication elements **138** also indicating the new values in real time. This enables the user to quickly control and modify the pulses **P** at the handpiece **104** in response to desired changes during a phacoemulsification procedure. The changes in the

parameter values correspondingly result in changes to the pulses P provided by the handpiece **104**.

**[0028]** In some of the embodiments as shown in FIG. 5, each of the control elements **136** of the GUI **134** may include a slider bar **152** juxtaposed on a scale **154**. One of the slider bars **152** may include a common tab **156** which when actuated moves both of the slider bars **152** simultaneously. In other embodiments, such as shown in FIG. 9, each of the control elements **136** may include a set of radio buttons **158** which may be actuated by means of the interface device **140** to increase and decrease the value of a respective parameter. In addition to a horizontal representation of the parameter values, vertical or circular representations may be used.

**[0029]** In addition to changing parameter values, the GUI **134** may also be utilized to change the shape of the pulse P. For example, as shown in FIG. 10, each of the control elements **136** may include a handle **160** juxtaposed over a graph **162** that, for example, represents the shape of the pulse P in terms of percentage power versus percentage of pulse ON time. A user may manipulate the position of the handles **160** with the interface device **140** to change the shape of the pulse P in real time.

**[0030]** In addition to displaying a GUI **134** for changing parameter values, the monitor **132** may also display a GUI **134** that can be utilized for changing the height of a bottle of irrigation fluid **128** mounted on an IV pole or for changing the pressure by which irrigation fluid is infused into the eye. More specifically, as shown in FIG. 11, in these embodiments, the control element **136** may include a slider bar **152** juxtaposed on a scale **154**. The GUI **134** may also include an icon **164** of the bottle of fluid **128** that is configured to move correspondingly with the slider bar **152** so that the scale **154** graphically represents the current height of the bottle. An indication element **138** may also numerically indicate the height as well.

**[0031]** With reference to FIG. 2, in use the needle **106** may be operatively inserted into an eye E. The user may then cause the control unit to provide the pulse P to the handpiece **104**, thereby causing the needle **106** to vibrate. One or more of the control element **136** may then be manipulated to manually change the value of respective parameters of the pulse P. In touchscreen **142** embodiments, the control element **136** may be moved or actuated by a user pressing a finger against the surface of the monitor **132** over the graphical representation of

the control element **136**, and then dragging, sliding, or moving the finger across the surface. In mouse **144** embodiments, the control element **136** may be moved by placing the pointer **151** on the graphical representation of the control element **136**, and then moving the element as desired. In keyboard **146** embodiments, designated keys may be associated with a parameter value so that by manipulating the keys, the value of the parameter changes.

**[0032]** Those skilled in the art will understand that the preceding exemplary embodiments of the present invention provide the foundation for numerous alternatives and modifications thereto. For example, in addition to the examples provided above, the interface device **140** may also a footswitch **164** as shown in FIG. **12** that is operably connected to the control unit **102**. A surgeon or surgical assistant can operate the footswitch **164** to provide inputs to the control unit **102** to, e.g., adjust the values of the parameters or change the irrigation fluid flow, as desired. In addition, the interface device **140** may also include a remote control **166** as shown in FIG. **13** that may either directly or wirelessly communicate with the control unit **102**. The remote control **166** may include a plurality of buttons **168** that correspond to the control elements **136** of the GUI **134** for surgical control of the parameters. These and other modifications are also within the scope of the present invention. Accordingly, the present invention is not limited to that precisely as shown and described above but by the scope of the appended claims.

**CLAIMS**

What is claimed is:

**1. An apparatus comprising:**

a handpiece including a needle and a vibrating unit for ultrasonically vibrating the needle according to a variable parameter;

a control unit operably coupled to the handpiece for adjusting the parameter;

a monitor operably connected to the control unit for displaying a graphical user interface (GUI), the GUI including an adjustable control element and an indication element, the indication element for indicating the value of the parameter; and

an interface device operably connected to the control unit for enabling a user to adjust the control element;

the control unit being configured to change the value of the parameter at least in response to adjustments of the control element by the user.

**2. The apparatus of claim 1 wherein the value of the parameter is changeable in real time.**

**3. The apparatus of claim 1 wherein interface device is adapted for manual adjustment of the control element by the user.**

**4. The apparatus of claim 1 wherein the vibrating unit further comprises a pulse that is controlled by the parameter.**

**5. The apparatus of claim 1 wherein the interface device includes a touchscreen operatively integrated with the monitor.**

**6. The apparatus of claim 1 wherein the interface device includes a mouse with an associated pointer integrated with the GUI.**

**7. The apparatus of claim 1 wherein the interface device includes a footswitch.**

**8. The apparatus of claim 1 wherein the interface device includes a remote control.**

**9. The apparatus of claim 1 wherein the control element includes a slider bar.**

**10. The apparatus of claim 1 wherein the control element includes radio buttons.**



11. The apparatus of claim 1 wherein the control element includes a handle.
12. The apparatus of claim 1 wherein the parameter includes a frequency of the pulse.
13. The apparatus of claim 1 wherein the parameter includes a size of the pulse.
14. The apparatus of claim 1 wherein the parameter includes a shape of the pulse.
15. The apparatus of claim 1 wherein the parameter includes an amplitude of the pulse.
16. The apparatus of claim 1 wherein the control unit is configured to cause the GUI to display the value of the parameter being provided to the handpiece in real time.
17. The apparatus of claim 1 wherein the vibrating unit of the handpiece vibrates the needle according to a plurality of parameters;  
the GUI including a corresponding plurality of control elements and indicator elements respectively associated with the plurality of parameters;  
the interface device being configured to enable the user to manually adjust each of the control elements independently of each other; and  
the control unit being configured to change the values of the parameters in response to adjustments of the control elements by the user and to provide the control signal to the vibrating unit of the handpiece with the changed values of the parameters in real time.
18. The apparatus of claim 1 wherein the GUI further includes an adjustable control element and an indication element associated with a height of a bottle of irrigation fluid mounted on an IV pole;  
the control unit being configured to change the height of the bottle at least in response to adjustments of the control element associated therewith by the user.

- 19.** A method for operating a phacoemulsification system, the method comprising:  
providing a phacoemulsification system including:  
a handpiece including a needle and a vibrating unit for ultrasonically vibrating  
the needle according to a variable parameter;  
a control unit operably coupled to the handpiece for adjusting the parameter;  
a monitor operably connected to the control unit for displaying a graphical user  
interface (GUI), the GUI including an adjustable control element and  
an indication element, the indication element for indicating the value of  
the parameter; and  
an interface device operably connected to the control unit for enabling a user  
to adjust the control element;  
the control unit being configured to change the value of the parameter at least  
in response to adjustments of the control element by the user;  
placing the handpiece in an operative relationship with an eye;  
causing the control unit to provide the control signal to the handpiece; and  
manipulating the control element of the GUI manually to change the value of the  
parameter.
- 20.** The method of claim **19** wherein the interface device includes a touchscreen  
operatively integrated with the monitor, the manipulating step comprising:  
contacting the touchscreen at the control element with a finger.
- 21.** The method of claim **19** wherein the interface device includes a mouse with an  
associated pointer integrated with the GUI, the manipulating step comprising:  
positioning the pointer on the control element.
- 22.** The method of claim **19** wherein the control element includes a slider bar, the  
manipulating step comprising:  
moving the slider bar.

**23.** The method of claim **19** wherein the control element includes radio buttons, the manipulating step comprising:

actuating the radio buttons.

**24.** The method of claim **19** wherein the control element includes a handle, the manipulating step comprising:

moving the handle.

**25.** The method of claim **19** wherein the parameter includes a frequency of the pulse, the manipulating step comprising:

manipulating the control element to change the value of the frequency of the pulse.

**26.** The method of claim **19** wherein the parameter includes a size of the pulse, the manipulating step comprising:

manipulating the slider bar to change the size of the pulse.

**27.** The method of claim **19** wherein the parameter includes pulse shape, the manipulating step comprising:

manipulating the slider bar to change the shape of the pulse.

**28.** The method of claim **19** wherein the vibrating unit of the handpiece vibrates the needle according to a plurality of parameters, the GUI includes a corresponding plurality of control elements and indicator elements respectively associated with the plurality of parameters, the interface device is configured to enable the user to manually adjust each of the control elements independently of each other, and the control unit is configured to change the values of the parameters in response to manipulation of the control elements by the user and to provide the control signal to the vibrating unit of the handpiece with the changed values of the parameters in real time, the manipulating step comprising:

manipulating at least one of the control element of the GUI manually to change the value of a corresponding one of the parameters.

**29.** A phacoemulsification system including an handpiece with a needle and vibrating unit for ultrasonically vibrating the needle according to a variable parameter, the system comprising:

a control unit operably coupled to the handpiece for adjusting the parameter;

a monitor operably connected to the control unit for displaying a graphical user interface (GUI), the GUI including an adjustable control element and an indication element, the indication element for indicating the value of the parameter; and

an interface device operably connected to the control unit for enabling a user to adjust the control element;

the control unit being configured to change the value of the parameter at least in response to adjustments of the control element by the user.

**30.** The system of claim **29** wherein the interface device includes a touchscreen operatively integrated with the monitor.

**31.** The system of claim **29** wherein the interface device includes a mouse with an associated pointer integrated with the GUI.

**32.** The system of claim **29** wherein the control element includes a slider bar.

**33.** The system of claim **29** wherein the control element includes radio buttons.

**34.** The system of claim **29** wherein the parameter includes a frequency of the pulse.

**35.** The system of claim **29** wherein the parameter includes a shape of the pulse.

**36.** The system of claim **29** wherein the parameter includes an amplitude of the pulse.

**37.** The system of claim **29** wherein the GUI further includes an adjustable control element and an indication element associated with a height of a bottle of irrigation fluid mounted on an IV pole;

the control unit being configured to change the height of the bottle at least in response to adjustments of the control element associated therewith by the user.

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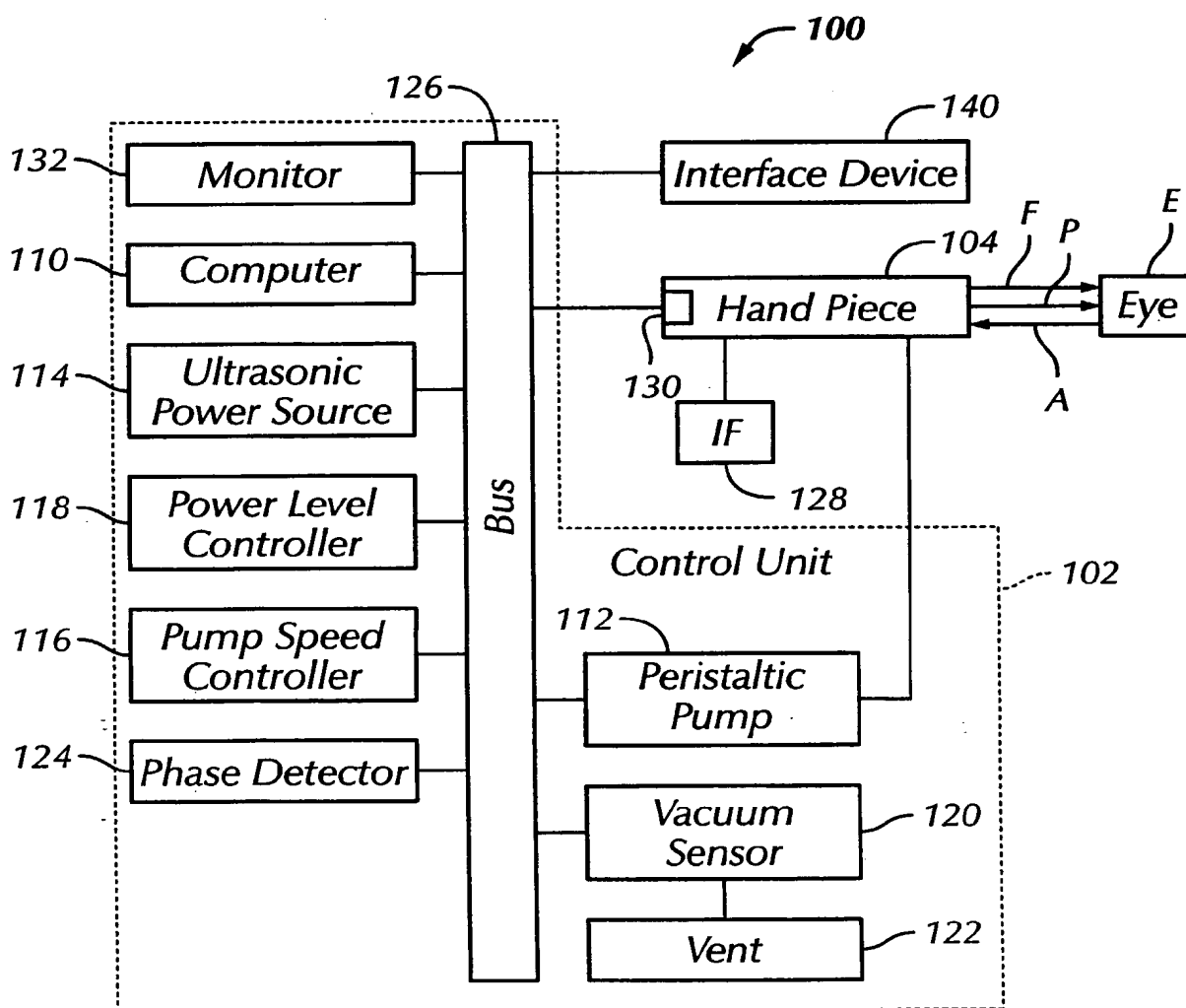


FIG. 1

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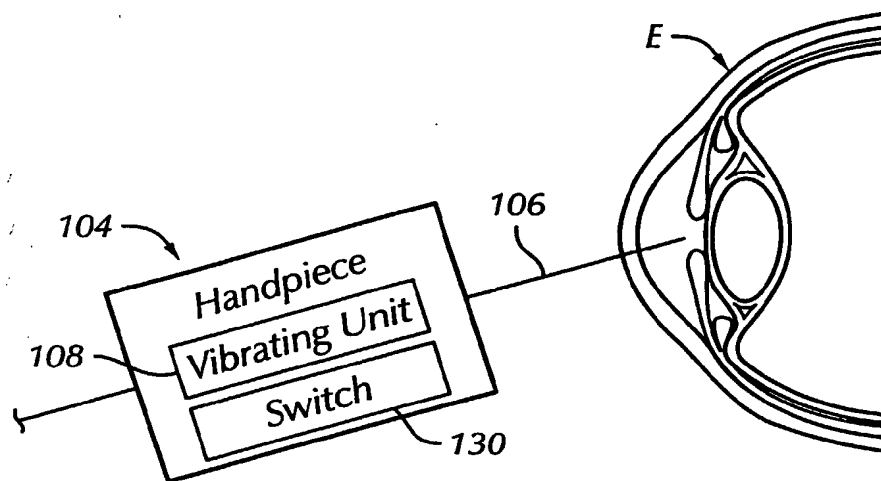


FIG. 2

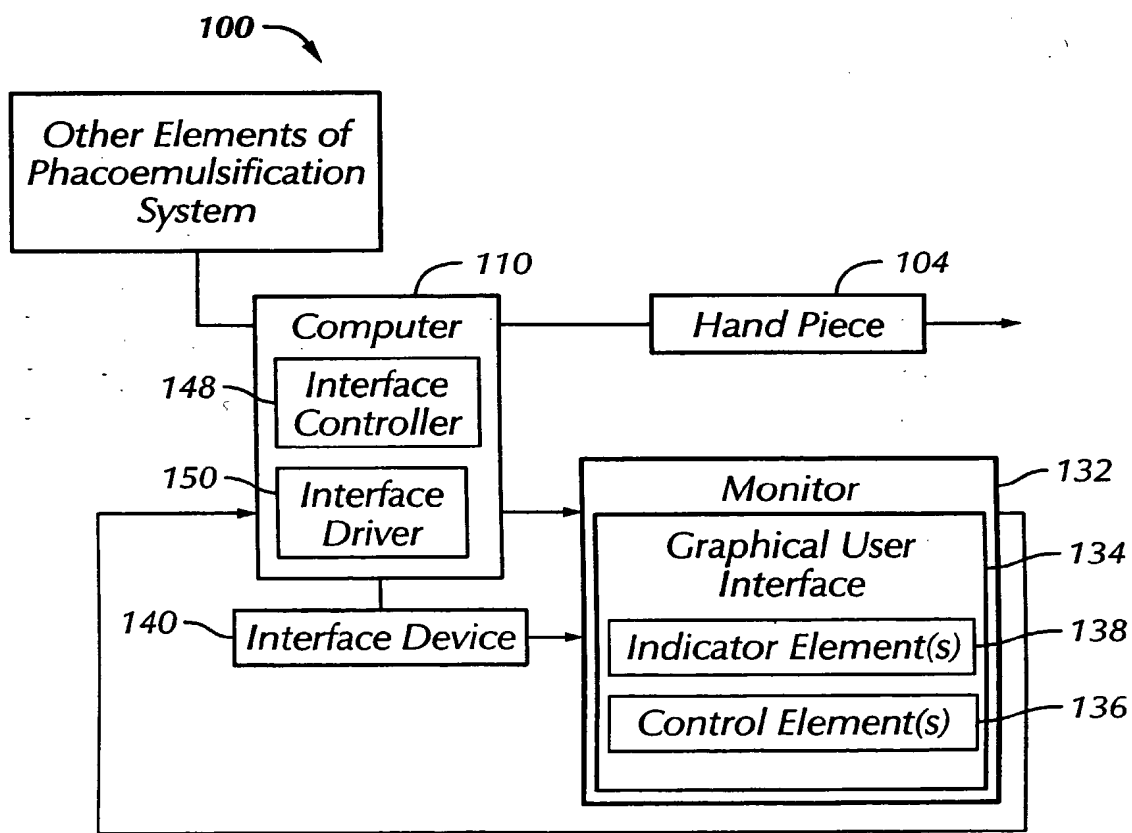


FIG. 4

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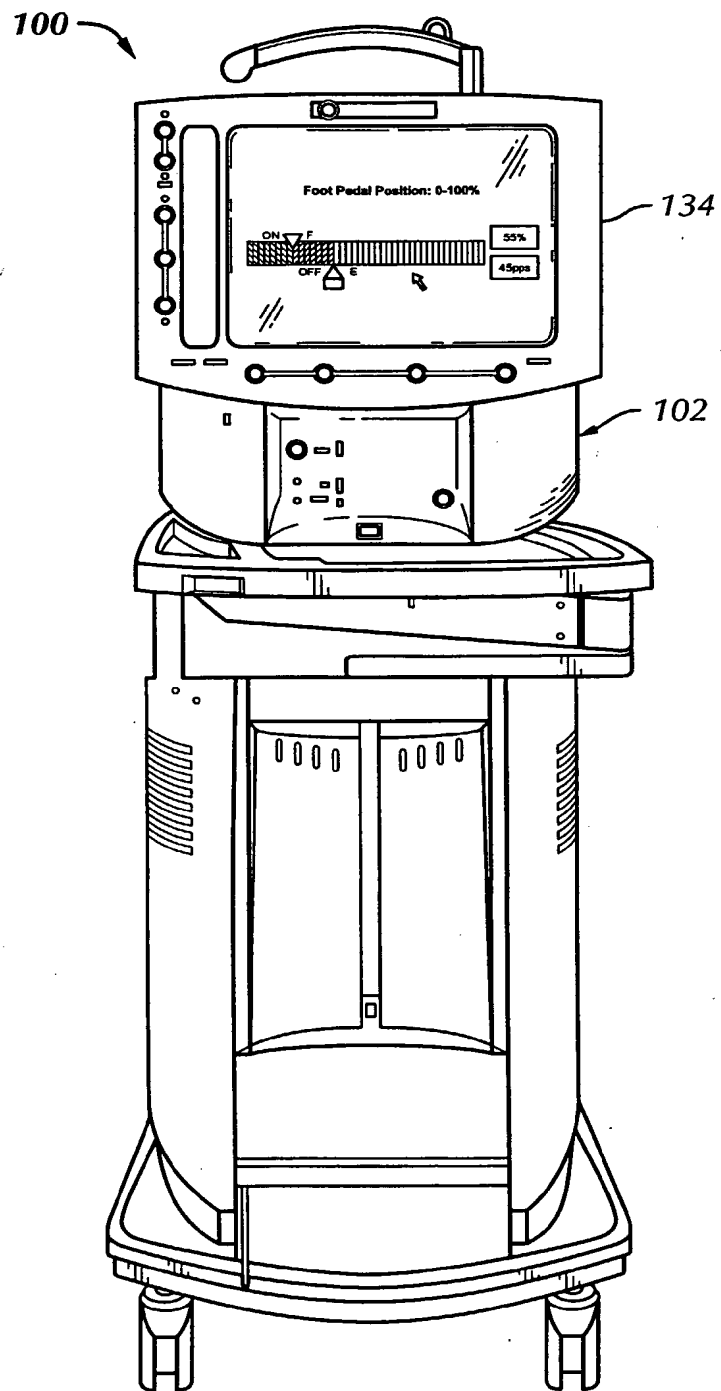


FIG. 3

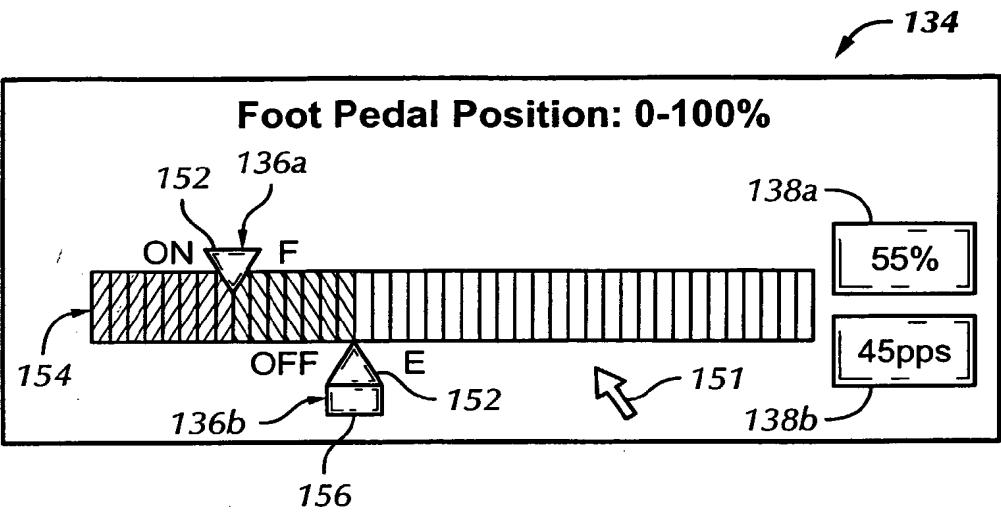


FIG. 5

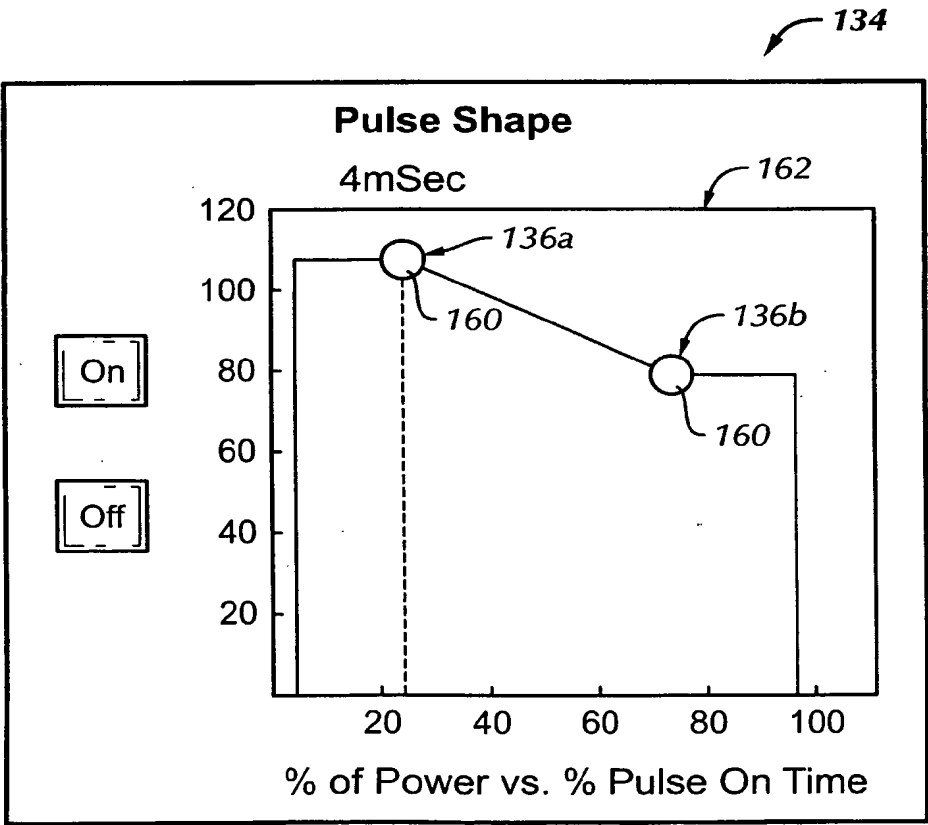


FIG. 10



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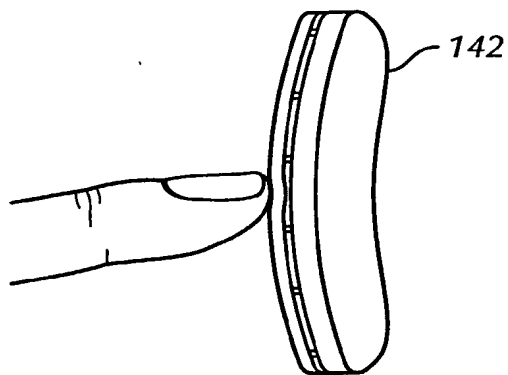


FIG. 6

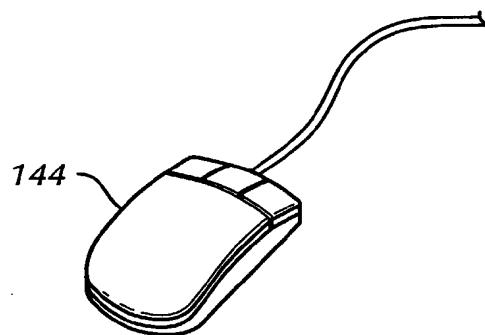


FIG. 7

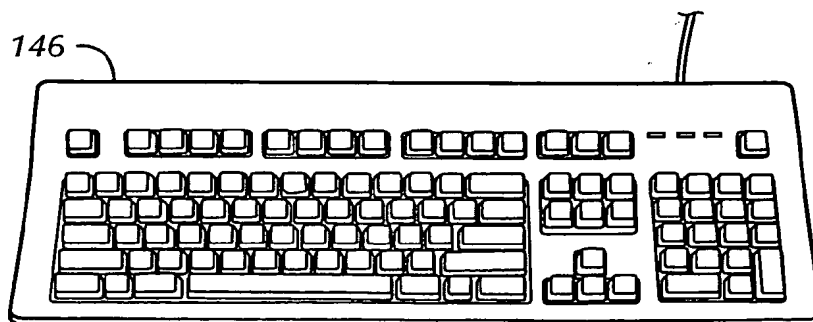


FIG. 8

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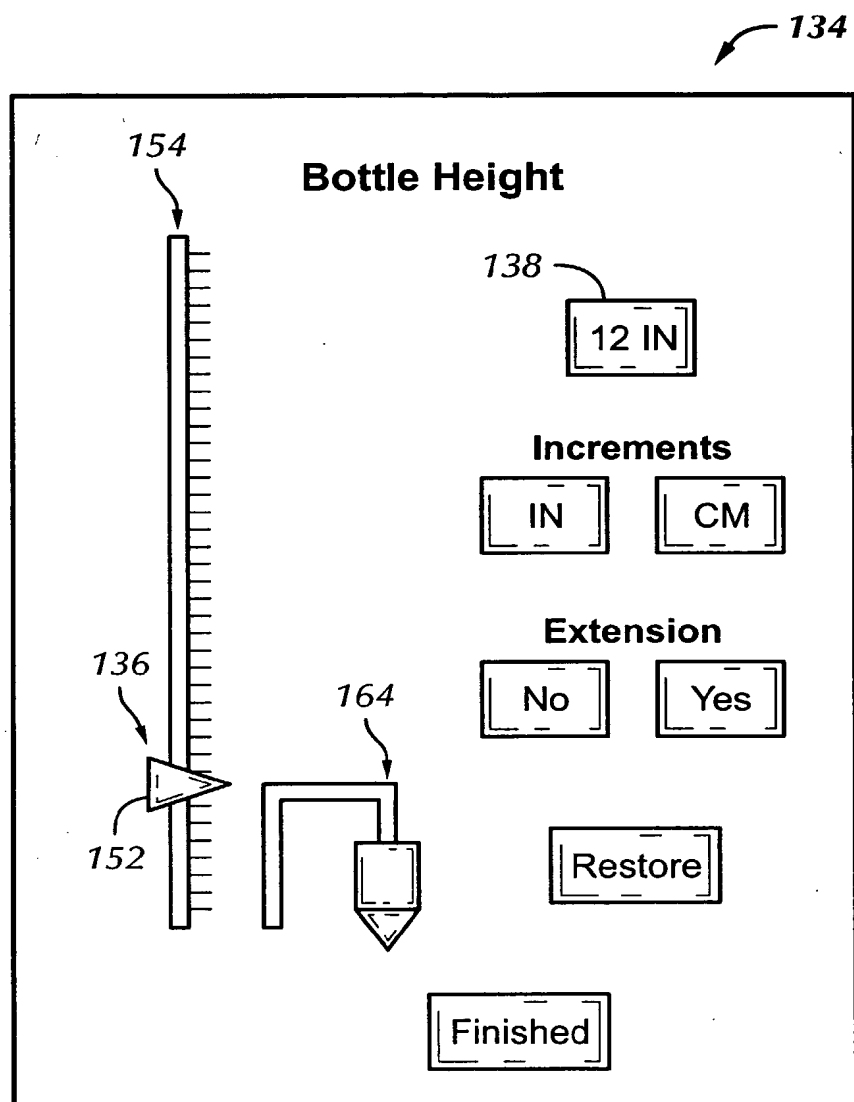


FIG. 11

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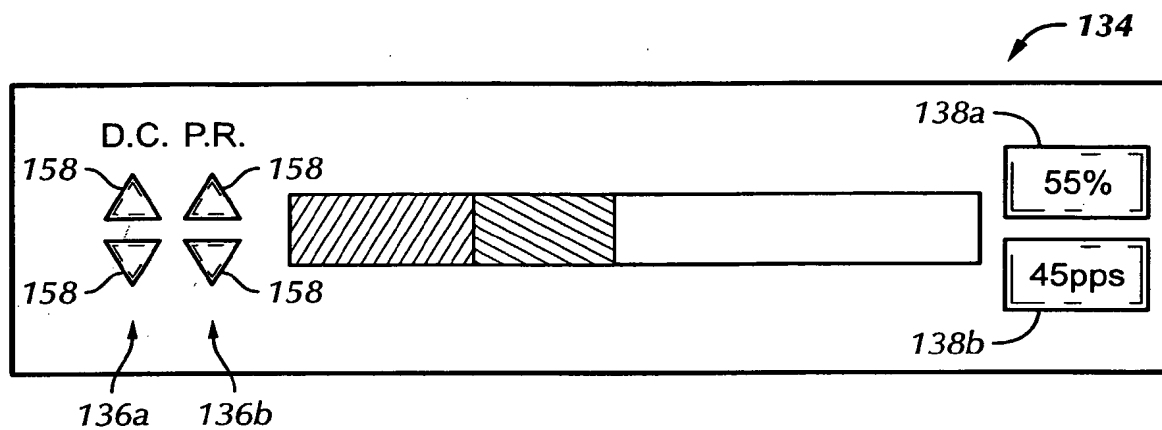


FIG. 9

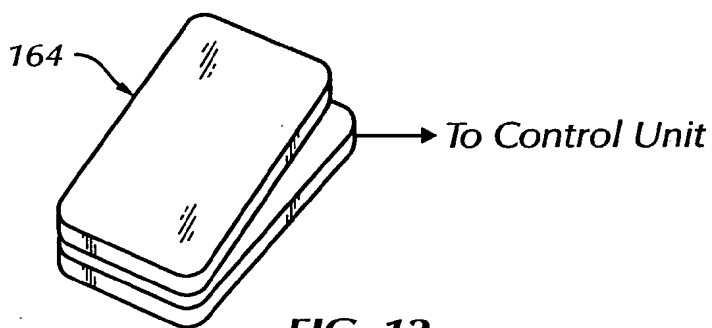


FIG. 12

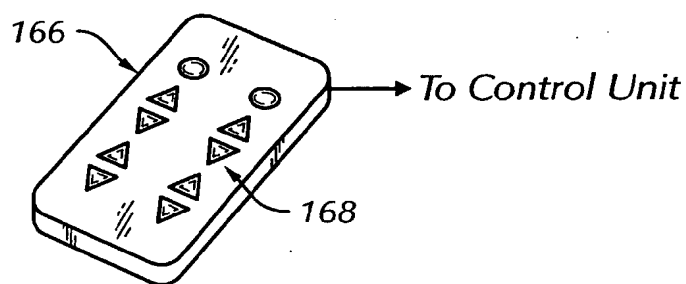


FIG. 13

## INTERNATIONAL SEARCH REPORT

International Application No.  
PCT/US2005/000310A. CLASSIFICATION OF SUBJECT MATTER  
IPC 7 A61F9/007

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC 7 A61F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 98/25556 A (CHIRON VISION CORPORATION) 18 June 1998 (1998-06-18) page 5, line 1 - page 10, line 22 page 13, line 22 - page 14, line 10 page 16, line 17 - line 23 figures 2,5	1-18, 29-37
X	US 6 251 113 B1 (APPELBAUM PETER FRANCIS ET AL) 26 June 2001 (2001-06-26) column 6, line 32 - column 7, line 25 column 13, line 46 - line 63 column 14, line 60 - column 15, line 15 column 18, line 22 - column 19, line 53 column 30, line 12 - line 35 figures 1,28-30	1-18, 29-37

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☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

8 July 2005

Date of mailing of the international search report

22/07/2005

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Authorized officer

Hooper, M

## INTERNATIONAL SEARCH REPORT

International Application No  
PCT/US2005/000310

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2001/003155 A1 (ROCKLEY PAUL W ET AL) 7 June 2001 (2001-06-07) cited in the application the whole document -----	1-18, 29-37

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US2005/000310

## Box II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.: 19-28  
because they relate to subject matter not required to be searched by this Authority, namely:  
Rule 39.1(iv) PCT - Method for treatment of the human or animal body by surgery
2. ☐ Claims Nos.:  
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

### Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

# INTERNATIONAL SEARCH REPORT

information on patent family members

International Application No

PCT/US2005/000310

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